Development Of Risk Assessment Matrix for
for
NASA Engineering and Safety Center (NESC)

Roy W. Malone, Jr.
Deputy Director of the Marshall Space Flight Center (MSFC)
Safety and Mission Assurance Directorate

Kelly D. Moses, P. E.
Sr. Risk Analyst
Futron Corporation

Expectations / Objectives for this Presentation

- Who we are and why we performed this exercise

- An understanding of (tasks, elements, actions) necessary to tailor a risk management scorecard and 5 x 5 risk matrix

- The approach proposed for use by NESC to develop 5 x 5 risk matrix scorecard as a tool in their decision process of accepting technical issues for further evaluation

- Proposed enhancements to a generic 5 x 5 risk matrix scorecard

- **Who we are**
  - ? Roy W. Malone, Jr.
    - Currently serving as Deputy Director of the Marshall Space Flight Center (MSFC) Safety and Mission Assurance Directorate
    - At time of this effort, NESC Technical Assistant to the Director
  - ? Kelly D. Moses, P. E.
    - Sr. Risk Analyst, Futron Corporation

- **How we tie in**
  - ? Roy tasked by Ralph Roe to develop a tool to aid in the NESC evaluation of candidate technical issues/actions using Futron's IRMA tool as a template.

- **What we were doing during this effort**
  - ? Developing a tool for use by NESC Chief Engineers in their assessment of the seriousness or potential impact of issues which have been forwarded to the NESC to be considered for assessment

- **Objective**

  To improve safety by performing in-depth engineering assessments, testing, and analysis to uncover technical vulnerabilities and to determine appropriate preventative and corrective actions for problems, trends or issues within NASA's programs, projects and institutions.

- **When**

  Created in the aftermath of the Space Shuttle Columbia accident. Became operational in November 2003.
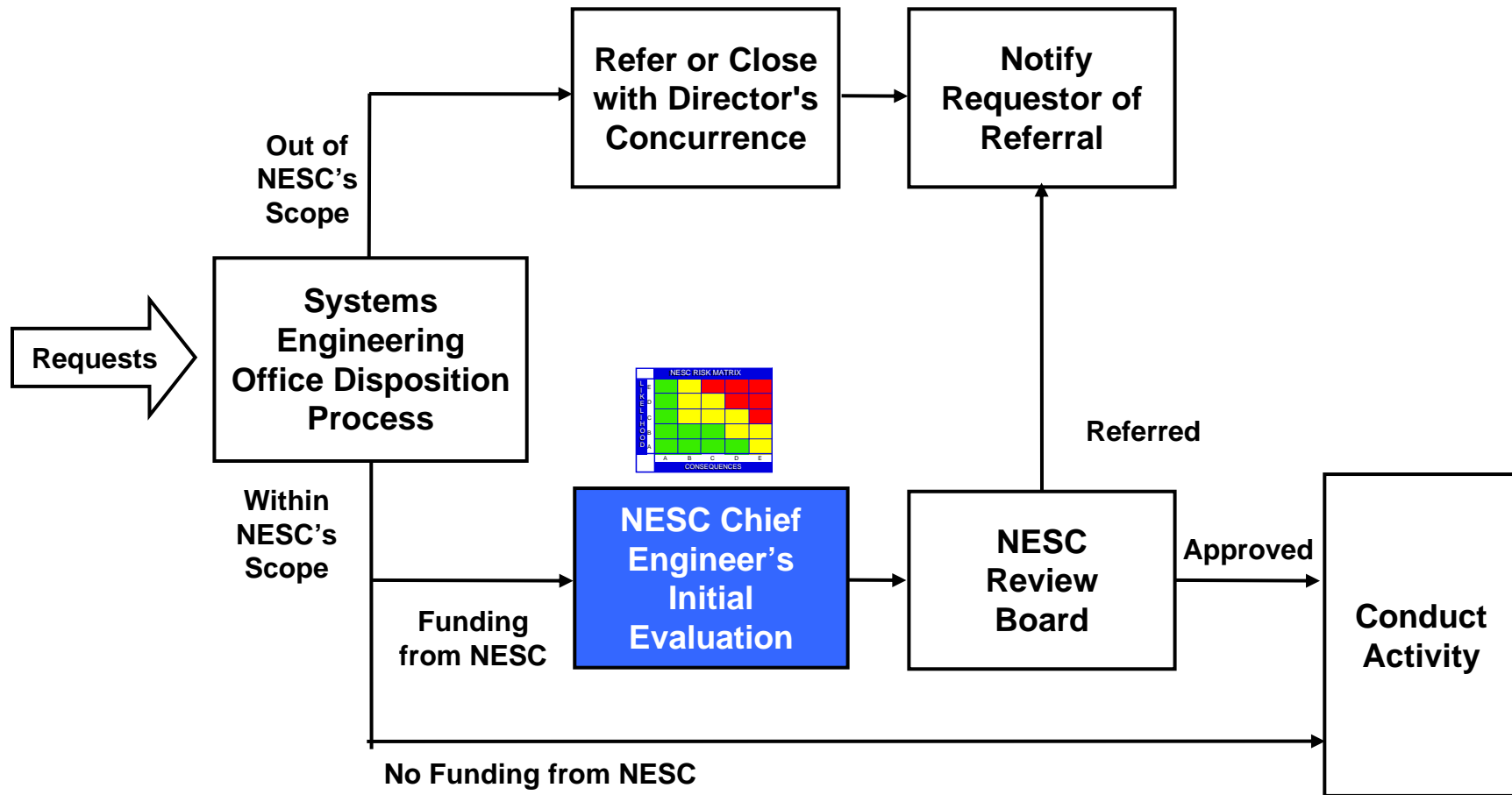
- **Where**

  Located at Langley Research Center, Hampton Virginia.
  NASA Headquarter's Function

- **Why**

  To serve as an independent technical resource for NASA managers and employees

NESC Prioritization Process

NESC Request Selection/Prioritization Process

NESC Chief Engineer Initial Evaluation

	Criteria
Risk	1. **Risk – Safety**
	2. **Risk – Mission Success**
	3. **Risk – National Importance**
	4. **Involves Deviation from Accepted Specification, Standard, or Practice**
Project	5. **Project Not Actively Engaged in Resolving Issue**
NESC Value	6. **Potential for Advancing Discipline Knowledge Base**
	7. **Resolution Lends Itself to Test and Analysis**
	8. **Perceived Urgency**

NESC RISK MATRIX — LIKELIHOOD (E, D, C, B, A) vs CONSEQUENCES (A, B, C, D, E)

Tailoring Considerations

- Used as a tool to help determine what issues will be addressed by the NESC

- Consequence
  - Safety, Health and Environment
  - Mission Success
  - National Significance

- Likelihood based on numerical probability ranges and associated real life examples (bootstrapping). To capture both schools of thought

- **Red**, **yellow** and **green** designations associated with recommended NESC action

- 'Per opportunity' probability values

- Used by program and project managers for risk management

- Consequence
  - Cost
  - Schedule
  - Technical

- Likelihood based on numerical probability ranges

- **Red**, **yellow** and **green** designations used to identify level of Risk

- Traditional 'per time' probability values

NESC RISK ASSESSMENT

| RISK DEFINITIONS | **Risk:** Measure of the potential inability to achieve overall program objectives within defined constraints and has two components: (1) the probability/likelihood of failing to achieve a particular outcome, and (2) the consequences/impacts of failing to achieve that outcome
 Consequence: Impact (typically categorized as negative) to program/project (loss, injury, disadvantage)
 Likelihood: Ordinal scale: Relative ranking of probability of occurrence. Numerical scale: estimated probability an event will occur combined with the uncertainty in the probability assessment | **RISK MANAGEMENT:** An organized, systematic decision-making process that efficiently identifies risks, assesses or analyzes risks, and effectively reduces or eliminates risks to achieving program goals. (NESC Risk Management Plan)
 NESC ASSESSMENT RISK MANAGEMENT APPLICATION (NARMA): The NESC database used to assess and prioritize concerns brought to the attention of the NESC. URL: http://xx |

What is the likelihood the situation or circumstance will happen?

Level	Probability	. . . or –. . .	Example
E	Very Likely	Likely to occur often. Likelihood of occurrence is estimated to be greater than 0.10 (10-1) per operational opportunity	Mortality Rate for Brain Surgery
D	High	Expected to occur some time in the life of the item. Likelihood of occurrence is estimated to be between 0.01 and 0.10 (10-2 and 10-1) per operational opportunity	Failures per US ELV Launch (1988 - 2001)
C	Moderate	Likely to occur some time in the life of the item. Likelihood of occurrence is estimated to be between 0.001 and 0.01 (10-3 and 10-2) per operational opportunity	Fatal Crashes per motorcycle trip
B	Low	Unlikely but possible to occur. Likelihood of occurrence is estimated to be between 0.000001 and 0.001 (10-6 and 10-3) per operational opportunity	Fatal crashes per automobile trip
A	Very Low	Likelihood of occurrence is estimated to be less than .000001 (<10-6) per operational opportunity	Fatal crashes per passenger airplane departure

NESC RISK MATRIX

LIKELIHOOD (E, D, C, B, A) vs CONSEQUENCES (A, B, C, D, E)

LEGEND

- **High** – Accepted for NESC Board review. Probable NESC follow-on IA.
- **Medium** – Accepted for NESC Board review. NESC or other NASA IA action required.
- **Low** – Accepted for NESC Board Review - Probable referral to other NASA IA org.

RISK CONSEQUENCE SCORING TERMS

1. Safety, Health, Environment is defined as impact to life, health, working environment and natural environment
2. Mission Success definition includes impacts to Major Mission Objectives (MMOs) as well as hardware loss
3. National Significance is defined as the degree to which national prestige, visibility and public relations are impacted
4. Safety, Health, Environment, Mission Success and National Significance can exist concurrently and are not mutually exclusive
5. Risk scoring is accomplished by numerical value which is reflective of the ordered pair L, C. When determining risk consequence among SHE, MS and NS, the highest score is represented in the NESC Risk Matrix as a single score value.

What is the Consequence (Safety, Health, Environment, Mission Success, National Significance) of this NESC Risk?

Level	A	B	C	D	E
Safety, Health, Environment	Minimal/no safety or health plan violations / Minimal to no environ impacts	Could result in injury or illness not resulting in lost work day / Minimal envirnmtl damage	Could result in injury or occupational illness resulting in one or more lost work day / Mit. envirnmtl damage w/o law viol	Could result in permanent partial disability, injuries or occupational illness / Reversible envinmt damage – violates law	Could result in death or perm. total disability / Irreversible severe environ damage that violates law or regulation
Mission Success	Hardware loss between $200K and $1 Million / Failure to any one MMO	Hardware loss between $1M and $10 Million / Failure to meet > 50% of supplemntl objectives	Hardware loss between $10M and $100 Million / Failure to meet any one MMO	Hardware loss between $100M and $250 Million / Failure to meet > 50% MMO's	Hardware loss exceeding $250 Million / Failure to meet all Major Mission Objectives (MMO's)
National Significance	Minimal or no identified National Prestige or Visibility	Low National Prestige and Visibility	Moderate National Prestige and Visibility	Significant National Prestige and Visibility	High National Prestige and Visibility

Key Efforts and Activities

Likelihood Definitions and Descriptors

		What is the likelihood the situation or circumstance will happen?		
	Level	Probability	. . . or –. . .	Example
L I K E L I H O O D	E	Very Likely	Likely to occur often. Likelihood of occurrence is estimated to be greater than 0.10 (10-1) per operational opportunity	Mortality Rate for Brain Surgery
	D	High	Expected to occur some time in the life of the item. Likelihood of occurrence is estimated to be between 0.01 and 0.10 (10-2 and 10-1) per operational opportunity	Failures per US ELV Launch (1988 - 2001)
	C	Moderate	Likely to occur some time in the life of the item. Likelihood of occurrence is estimated to be between 0.001 and 0.01 (10-3 and 10-2) per operational opportunity	Fatal Crashes per motorcycle trip
	B	Low	Unlikely but possible to occur. Likelihood of occurrence is estimated to be between 0.000001 and 0.001 (10-6 and 10-3) per operational opportunity	Fatal crashes per automobile trip
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Consequence Scoring Terms

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Consequence Level Definitions

	Level	A	B	C	D	E
C O N S E Q U E N C E	**Safety, Health, Environment**	Minimal/no safety or health plan violations / Minimal to no environ impacts	Could result in injury or illness not resulting in lost work day / Minimal envirnmtl damage	Could result in injury or occupational illness resulting in one or more lost work day / Mit. envirnmtl damage w/o law viol	Could result in permanent partial disability, injuries or occupational illness / Reversible envinmt damage – violates law	Could result in death or perm. total disability / Irreversible severe environ damage that violates law or regulation
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What is the Consequence (Safety, Health, Environment, Mission Success, National Significance) of this NESC Risk?

Risk Levels and the 5 x 5 Risk Matrix

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NESC RISK MATRIX

LIKELIHOOD	A	B	C	D	E
E	green	yellow	red	red	red
D	green	yellow	yellow	red	red
C	green	yellow	yellow	yellow	red
B	green	green	green	yellow	yellow
A	green	green	green	green	yellow

CONSEQUENCES

Proposed Enhancements

# *Uncertainty:*
How to Capture and Communicate

- Concerns
  - Potential Cases with Significant Amount of Uncertainty
  - How Can Uncertainty be Captured & Communicated
- Recommended Potential Solutions to be Investigated
  - Predetermined Uncertainty Level

    Develop categories of uncertainty levels

Uncertainty Level	Uncertainty % of Estimate	Score	Criteria for System	Score	Criteria for Assessor
5	200	E	No data available	E	No experience
4	100	D	system remotely similar	D	Little Experience
3	50	C	Little Data Similar System	C	Some Experience
2	25	B	Data Similar Equipment	B	Expert Similar system
1	10	A	Data on Exact System	A	Expert in System

  - Assessed Uncertainty Level (Self or Others)

    Methods for Uncertainty/Confidence Bounds

NESC RISK MATRIX

LIKELIHOOD

CONSEQUENCES
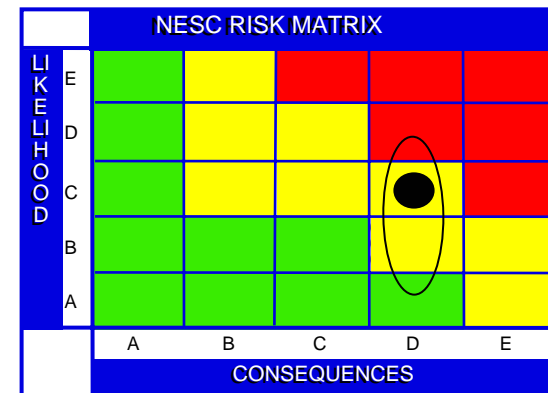
Communicating Risks Using the Risk Matrix

- Information Communicated by Placement within Risk Matrix
  - ? More than one 'dot' use three separate denotations, M, S, N

  - ? Avoid Math of Matrix Placement – Levels are ONLY Ordinal
    - Use ordered pair of (likelihood, consequence) (4,3)
    - Use letters for likelihood and consequence levels (D, C)

Summary and Conclusions

Summary

- A risk matrix can be a flexible and powerful tool
- Easy to tailor
- We have demonstrated an example of an innovative application
- Broke up technical and went a level deeper
- Bootstrapping facilitates clarity and understanding in addition to providing more of a human perspective.
- Communication using 'bounds' can more realistically demonstrate the uncertainty in an initial assessment

Acknowledgements

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- Any opinions, findings, or conclusions expressed here are those of the authors and do not necessarily reflect the views of the Administration

Back up

Likelihood Research

Event	Likelihood per operational opportunity	Level	Source
Fatal crashes / passenger airline departure	4.5×10^{-7}	Level 1 (<10-6 per operational opportunity)	4
Fatalities / Public Bus trip	3.5×10^{-5}	Level 2 (10-6 and 10-3 per operational opportunity)	5
Fatalities / passenger vehicle trip	7.5×10^{-5}	Level 2	6
Fatalities / motorcycle trip (20 mile avg trip)	6.6×10^{-4}	Level 2	7
Fatalities / motorcycle trip (50 mile avg trip)	1.65×10^{-3}	Level 3 (10-3 and 10-2 per operational opportunity)	7
Failures of ELV per launch	4.5×10^{-2}	Level 4 (10-2 and 10-1 per operational opportunity)	8
Mortality Rate Open Heart Surgery	2.2×10^{-2}	Level 4	9
Aortic Replacement Surgery	6.1×10^{-2} to 1.02×10^{-1}	Borderline Level 4/5	10, 11
Mortality Brain Surgery (Craniectomies)	2.2×10^{-1}	Level 5 greater than 0.10 (10-1) per operational opportunity	12,13